Amendments to the Claims

1. (Previously Presented) A micro-transducer comprising:

a first membrane;

a second membrane comprising a first electrode, a second electrode, and a piezoelectric member disposed therebetween;

a fluid-tight cavity cooperatively formed between the first and second membranes; and

a working fluid disposed in the cavity, wherein the working fluid is a saturated mixture of vapor and liquid.

2. (Original) The micro-transducer of claim 1, further comprising a low-temperature heat sink disposed adjacent the first membrane and a high-temperature heat source disposed adjacent the second membrane such that the transducer is operative as a micro-heat engine having a thermodynamic cycle, wherein thermal energy, flowing from the high-temperature heat source to the low-temperature heat sink through the micro-heat engine during the thermodynamic cycle, is converted into electrical energy.

3. (Original) The micro-transducer of claim 2, wherein the low-temperature heat sink has at least one thermal switch positioned to thermally couple the low-temperature heat sink and the first membrane at least once during the thermodynamic cycle of the micro-heat engine and the high-temperature heat source has at least one thermal switch positioned to thermally couple the high-temperature heat source and the second membrane at least once during the thermodynamic cycle of the micro-heat engine.

4. (Original) The micro-transducer of claim 1, further comprising a low-temperature heat source disposed adjacent the second membrane and a high-temperature heat sink disposed adjacent the first membrane such that the transducer is operative as a micro-heat pump having a thermodynamic cycle, wherein electrical energy is consumed to transfer heat from the low-temperature heat source to the high-temperature heat sink.

5. (Original) The micro-transducer of claim 4, wherein the low-temperature heat source has at least one thermal switch positioned to thermally couple the low-temperature heat source and the second membrane at least once during the thermodynamic cycle of the micro-heat pump, and the high-temperature heat sink has at least one thermal switch positioned to thermally couple the high-temperature heat sink and the first membrane at least once during the thermodynamic cycle of the micro-heat pump.

6. (Canceled)

7. (Original) The micro-transducer of claim 1, wherein the first membrane comprises a layer of silicon, and the second membrane comprises a layer of silicon for supporting the first and second electrodes and the piezoelectric member.

8. (Original) A micro-transducer comprising:

a first layer;

a second layer having piezoelectric properties and joined to the first layer so as to form a fluid-tight cavity therebetween; and

a working fluid contained within the cavity;

wherein thermal energy flowing into the micro-transducer causes the working fluid to expand, thereby distending the second layer for generating an electrical charge.

9. (Original) The micro-transducer of claim 8, wherein the first layer comprises a first substrate forming a first membrane, and the second layer comprises a second substrate forming a second membrane, the micro-transducer further comprising an intermediate layer between the first and second layers and defining a recess, the first membrane, the second membrane and the recess together defining the fluid-tight cavity.

10. (Original) The micro-transducer of claim 8, wherein the working fluid is at least a vapor phase.

11. (Original) The micro-transducer of claim 8, further comprising a high-temperature heat source positioned to transfer heat energy into the micro-transducer.

12. (Original) The micro-transducer of claim 11, wherein the high-temperature heat source is positioned to thermally conduct heat energy into the micro-transducer.

13. (Original) The micro-transducer of claim 8, further comprising a low-temperature heat sink positioned to receive heat energy from the micro-transducer.

14. (Original) The micro-transducer of claim 13, wherein the low-temperature heat sink is positioned to receive heat energy from the micro-transducer through conduction.

15. (Original) The micro-transducer of claim 8, wherein the first layer is more rigid than the second layer so that the second layer distends outwardly and the first layer retains a substantially constant profile whenever heat energy flows into the micro-transducer to expand the working fluid.

16. (Previously Presented) A structure having a plurality of micro-transducers, the structure comprising:

a first major layer;

a second major layer juxtaposed to the first layer;

a plurality of fluid-tight cavities cooperatively formed between the first and second major layers;

a working fluid contained in the cavities;

a plurality of first electrodes carried by the first major layer at each of said cavities;

a plurality of piezoelectric members carried by the first electrodes at each of said cavities; and

a plurality of second electrodes carried by the piezoelectric members at each of said cavities;

wherein the first electrodes comprise a unitary first metallic layer overlaying the first surface, the plurality of piezoelectric members comprise a unitary piezoelectric layer overlaying

the first metallic layer, and the plurality of second electrodes comprise a unitary second metallic layer overlaying the piezoelectric layer.

17. (Previously Presented) The structure of claim 16, wherein the working fluid occupies the cavities.

18. (Previously Presented) A structure having a plurality of micro-transducers, the structure comprising:

a first major layer;

a second major layer juxtaposed to the first layer;

a plurality of fluid-tight cavities cooperatively formed between the first and second major layers;

a working fluid contained in the cavities;

a plurality of first electrodes carried by the first major layer at each of said cavities;

a plurality of piezoelectric members carried by the first electrodes at each of said cavities; and

a plurality of second electrodes carried by the piezoelectric members at each of said cavities;

wherein the first major layer comprises a first substrate and the second major layer comprises a second substrate, the first substrate having a plurality of recessed portions defining first membranes of the micro-transducers, and the second substrate having a plurality of recessed portions aligned with the recessed portions of the first substrate and defining second membranes of the micro-transducers.

19. (Currently Amended) A structure having a plurality of micro-transducers, the structure comprising:

a <u>continuous,</u> first major layer;

a <u>continuous,</u> second major layer juxtaposed to the first layer;

a plurality of fluid-tight cavities cooperatively formed between the first and second major layers;

a working fluid contained in the cavities;

a plurality of first electrodes carried by the first major layer at each of said cavities;

a plurality of piezoelectric members carried by the first electrodes at each of said cavities;

a plurality of second electrodes carried by the piezoelectric members at each of said cavities; and

an intermediate layer disposed between the first and second major layers, the intermediate layer defining a plurality of recesses that define respective cavities between the first and second major layers.

20. (Original) The structure of claim 19, wherein the intermediate layer comprises a photo-resist material.

21. (Previously Presented) A structure having a plurality of micro-transducers, the structure comprising:

a first major layer;

a second major layer juxtaposed to the first layer;

a plurality of fluid-tight cavities cooperatively formed between the first and second major layers;

a working fluid contained in the cavities;

a plurality of first electrodes carried by the first major layer at each of said cavities;

a plurality of piezoelectric members carried by the first electrodes at each of said cavities; and

a plurality of second electrodes carried by the piezoelectric members at each of said cavities;

wherein the working fluid is a saturated mixture of vapor and liquid.

22-74. (Canceled)

75. (Previously Presented) A micro-transducer, comprising:

a first membrane;

a second membrane comprising a first electrode, a second electrode, and a piezoelectric member disposed therebetween;

a fluid-tight cavity cooperatively formed between the first and second membranes;

a working fluid disposed in the cavity; and

a low-temperature heat sink disposed adjacent the first membrane and a high-temperature heat source disposed adjacent the second membrane such that the transducer is operative as a micro-heat engine having a thermodynamic cycle, wherein thermal energy, flowing from the high-temperature heat source to the low-temperature heat sink through the micro-heat engine during the thermodynamic cycle, is converted into electrical energy.

76. (Previously Presented) The micro-transducer of claim 75, wherein:

the low-temperature heat sink has at least one thermal switch positioned to thermally couple the low-temperature heat sink and the first membrane at least once during the thermodynamic cycle of the micro-heat engine; and

the high-temperature heat source has at least one thermal switch positioned to thermally couple the high-temperature heat source and the second membrane at least once during the thermodynamic cycle of the micro-heat engine.

77. (Previously Presented) The micro-transducer of claim 75, wherein the working fluid comprises a saturated vapor and liquid.

78. (Previously Presented) The micro-transducer of claim 75, wherein:

the first membrane comprises a layer of silicon; and

the second membrane comprises a layer of silicon for supporting the first and second electrodes and the piezoelectric member.

79. (Previously Presented) The micro-transducer of claim 77, wherein the cavity is configured such that the liquid adheres to inside surfaces of the cavity due to surface tension of the liquid, thereby resulting in separation of the liquid from the vapor.

80. (Previously Presented) The micro-transducer of claim 75, wherein the working fluid occupies the cavity.

81. (Previously Presented) The micro-transducer of claim 75, wherein the first membrane is more rigid than the second membrane such that the second membrane deflects and the first membrane retains a substantially constant profile during the thermodynamic cycle.

82. (Previously Presented) A micro-transducer, comprising:

a first membrane;

a second membrane comprising a first electrode, a second electrode, and a piezoelectric member disposed therebetween;

a fluid-tight cavity cooperatively formed between the first and second membranes;

a working fluid occupying substantially the entire cavity; and

a low-temperature heat source disposed adjacent the second membrane and a high-temperature heat sink disposed adjacent the first membrane such that the transducer is operative as a micro-heat pump having a thermodynamic cycle, wherein electrical energy is consumed to transfer heat from the low-temperature heat source to the high-temperature heat sink.

83. (Previously Presented) The micro-transducer of claim 82, wherein:

the low-temperature heat source has at least one thermal switch positioned to thermally couple the low-temperature heat source and the second membrane at least once during the thermodynamic cycle of the micro-heat pump; and

the high-temperature heat sink has at least one thermal switch positioned to thermally couple the high-temperature heat sink and the first membrane at least once during the thermodynamic cycle of the micro-heat pump.

84. (Previously Presented) The micro-transducer of claim 82, wherein the working fluid comprises a saturated vapor and a liquid.

85. (Previously Presented) The micro-transducer of claim 82, wherein:

the first membrane comprises a layer of silicon; and

the second membrane comprises a layer of silicon for supporting the first and second electrodes and the piezoelectric member.

86. (Previously Presented) The micro-transducer of claim 84, wherein the cavity is configured such that the liquid adheres to inside surfaces of the cavity due to surface tension of the liquid, thereby resulting in separation of the liquid from the vapor.

87. (Previously Presented) The micro-transducer of claim 82, wherein the first membrane is more rigid than the second membrane such that the second membrane deflects and the first membrane retains a substantially constant profile during the thermodynamic cycle.

88. (Previously Presented) A micro-transducer, comprising:

a body defining a fluid-tight cavity;

a compressible and expansible working fluid contained within and occupying the cavity, the body having a piezoelectric unit situated adjacent the cavity, and the piezoelectric unit being operable as an actuator to compress the working fluid whenever an electric field is applied to the piezoelectric unit and operable as a generator to generate an electric charge whenever the working fluid expands;

a heat source; and

a heat sink, the heat source and heat sink being positioned relative to the body such that thermal energy flowing from the heat source to the heat sink flows through the working fluid.

89. (Previously Presented) The micro-transducer of claim 88, wherein:

the heat source is a high-temperature heat source;

the heat sink is a low-temperature heat sink; and

the transducer is operable as a micro-heat engine according to a thermodynamic cycle in which thermal energy, flowing from the heat source to the heat sink through the working fluid, is converted into electrical energy.

90. (Previously Presented) The micro-transducer of claim 88, wherein:

the heat source is a low-temperature heat source;

the heat sink is a high-temperature heat sink; and

the micro-transducer is operative as a micro-heat pump that consumes electrical energy while transferring heat from the low-temperature heat source to the high-temperature heat sink.

91. (Previously Presented) The micro-transducer of claim 88, wherein the working fluid comprises a vapor and a liquid.

92. (Previously Presented) The micro-transducer of claim 91, wherein the cavity is configured such that the liquid adheres to inside surfaces of the cavity due to surface tension of the liquid, thereby resulting in separation of the liquid from the vapor.

93. (Previously Presented) The micro-transducer of claim 88, wherein:

the body comprises first and second opposed major layers;

the cavity is formed between the first and second layers; and

the cavity has a thickness defined between the first and second layers of about 50 microns or less.

94. (Previously Presented) An apparatus for converting energy in one form to energy in another form, the apparatus comprising:

a first major layer; and

a second major layer juxtaposed to the first major layer, the first and second major layers forming a plurality of micro-transducers, each micro-transducer comprising a respective fluid-tight cavity formed between the first and second major layers, a compressible working fluid disposed in the cavity, and a respective piezoelectric unit formed on one of the first and second major layers.

95. (Previously Presented) The apparatus of claim 94, wherein:

the first and second major layers form a first level of micro-transducers;

the apparatus further comprises a second level comprising third and fourth major layers forming a respective plurality of micro-transducers, each micro-transducer comprising a respective fluid cavity formed between the third and fourth major layers, a working fluid disposed in the cavity, and a respective piezoelectric unit formed on one of the third and fourth major layers; and

the second level of micro-transducers are stacked superposedly with respect to the first level of micro-transducers.

96. (Previously Presented) The apparatus of claim of claim 95, wherein each micro-transducer of the first level is aligned with a respective micro-transducer of the second level.

97. (Previously Presented) The apparatus of claim 95, further comprising a plurality of thermal contacts positioned between the first and second levels to facilitate transfer of thermal energy from the micro-transducers of the first level to the micro-transducers of the second level.

98. (Previously Presented) The apparatus of claim 94, wherein:

the first major layer comprises a first substrate having a plurality of recessed portions and piezoelectric units formed on the recessed portions, the piezoelectric units and recessed portions defining first membranes of the micro-transducers; and

the second major layer comprises a second substrate having a plurality of recessed portions aligned with respective recessed portions of the first substrate and defining second membranes of the micro-transducers.

99. (Previously Presented) The apparatus of claim 98, further comprising an intermediate layer disposed between the first and second substrates and defining a plurality of apertures, the fluid cavities of the micro-transducers being defined by the first and second membranes and respective apertures in the intermediate layer.

100. (Previously Presented) An energy-conversion apparatus, comprising:

a first pair of first and second substrates forming a respective plurality of micro-transducers, each micro-transducer having a respective fluid cavity formed between the first pair of first and second substrates, a working fluid disposed in the fluid cavity, and a respective piezoelectric unit carried on one of the first and second substrates of the first pair; and

a second pair of first and second substrates forming a respective plurality of micro-transducers, each micro-transducer having a respective fluid cavity formed between the second pair of first and second substrates, a working fluid disposed in the fluid cavity, and a respective

piezoelectric unit carried on one of the first and second substrates of the second pair, wherein the first pair of substrates is stacked superposedly with respect to the second pair of substrates.

101. (Previously Presented) The apparatus of claim 100, wherein the micro-transducers of the first pair of substrates are aligned with the micro-transducers of the second pair of substrates.

102. (Previously Presented) The apparatus of claim 100, further comprising a heat source and a heat sink positioned to allow thermal energy to flow from the heat source to the heat sink, through the micro-transducers of the first pair of substrates, and through the micro-transducers of the second pair of substrates.

103. (Previously Presented) The apparatus of claim 100, wherein the working fluid of each micro-transducer comprises a liquid portion and a saturated vapor portion.

104. (Previously Presented) A micro-transducer, comprising:

a body defining a fluid-tight cavity; and

a compressible and expansible working fluid contained within the cavity, the body having a piezoelectric unit situated adjacent the cavity, and the piezoelectric unit being operable as an actuator to compress the working fluid whenever an electric field is applied to the piezoelectric unit and operable as a generator to generate an electric charge whenever the working fluid expands.

105. (Previously Presented) The micro-transducer of claim 104, wherein the working fluid occupies the cavity.

106. (Previously Presented) The micro-transducer of claim 104, wherein:

the body comprises a first membrane and a second membrane;

the cavity is formed between the first and second membranes; and

the piezoelectric unit is disposed on the first membrane.

107. (Previously Presented) The micro-transducer of claim 106, wherein the first membrane is more flexible than the second membrane.